

An Investigation of the Solid Particulate Collection Efficiency
of the Traverse - Rake - Type Stack Probe

7-12 CENTRAL FILES

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Process vent stacks at the Y-12 Plant at Oak Ridge, Tennessee are monitored continuously on a routine basis for the emission of enriched uranium in solid particulate matter. Although only small losses are involved, measurement must be made ~~for frequent inventory balances~~

to insure adequate control of those losses

Choice of Probe

For years, sampling has been accomplished through the use of a tube with a 90° curved end inserted through the wall of an exhaust stack with the end pointed upstream. In a recent review of inventorying methods, plans were made to upgrade the measurement of stack emissions by the choice of equipment of improved design for representative sampling and actual evaluation tests using a stack spiking technique once such equipment was found.

The problem was complicated by the suspected, and subsequently confirmed, uneven velocity and dust loading patterns which existed even on vertical runs because of the design of the plant exhaust installations.

Logically, collecting one sample that is representative from a single point inside a stack is a simpler and more expedient process than the collection from multiple points on a crosssection in an attempt to achieve representativeness. Some success in achieving such a sample from a single point has been reported in the past through the use of flow-mixing devices introduced into the stack upstream from the sampler. However, the heads, which must be developed to maintain exhaust flow, made this approach unattractive.

A recently reported device for obtaining a continuous representative sample from the crosssections of circular stacks consists of a rotating manifold tube, the length of which is approximately equal to the diameter of the stack. Multiple-sampling nozzles are spaced along the length of the tube to provide full coverage of the stack diameter. Local samples are drawn into the manifold and from there into a single filter outside the stack. The principles commonly applied to traverses for velocity determinations are used for the location of the nozzles at the centers of equal areas of the crosssection. Rotation of the unit is carried out at a low, fixed speed about the axis of the manifold. The net result is essentially a sampling along an infinite number of stack diameters. For our case, this design was ruled out because of cost.

A probe similar to the manifold tube just described but without the rotating feature, known as the "traverse type" probe, was chosen as best suited to plant needs. The design is similar to one proposed by Haines and Hemeon at the Industrial Hygiene Foundation, Pittsburgh, Pa. The probe being stationary, yet equipped to draw simultaneously multiple local samples across any crosssection, appeared to offer a simple, practical plant device if a continuous representative sample could be attained.

Choice of Stack

An operating plant stack with uranium-free exhaust was chosen as pilot stack. The installation was similar in size and design to most of those which required routine monitoring. The walls were dry and non-coated so that chance adherence of impacting spike material could be kept to a minimum. Finally, the physical layout was such that introduced spike would be directed to about the center of the stack and immediately dispersed in the exhaust stream rather than allowed to strike against stack walls before dispersion.

Choice of Spike

Particles emitted from Y-12 stacks are a mixture of uranium oxide, dirt, rust, and others chiefly dry contaminants. The overall density falls in the range of 7 to 8 grams/cc. Collected emissions from the stacks were found to contain particles in the size range of 0.0125 to 4 microns, and an average of about 1/2 micron.

It was necessary that the material to serve as spike conform to the physical properties of the usual stack particulates as closely as possible. The material chosen consisted of a conveniently available mixture of ~~non-enriched~~ ^{non-enriched} uranium in carbon dust with a mean density of 6.7 grams/cc and a particle size range of from 0.5 μ to 5.5 μ . Chemical analysis indicated about 75% uranium; exact analyses of each batch used preceded usage in the tests.

Probe Details and Usage

During the progress of the tests, small variations in the design of the probe were made while the basic design philosophies were retained. The changes came about in an attempt to incorporate what were considered minor improvements in the design and to detect possible resultant changes in sampling efficiency. The probes are shown on the first slide.

For the first and second runs, Probe 1 was used; for runs 3 through 5, Probe 2 was used; and for the subsequent runs 6 through 16, Probe 3, the traverse rake was used. Probe design was initially influenced by the following factors to which sampling efficiency was considered sensitive: isokinetic sampling conditions, gravitational settling, electrical attraction between particulate matter and probe wall, and turbulence within the probe. All probes were designed for isokinetic sampling at the sampling aperture at as near laminar flow as possible by judicious choice of the number of sampling nozzles and nozzle diameter sizes together with changes in the sampling rate. This approach was actually somewhat tricky so that approaches to the desired conditions rather than the absolute ideal conditions were accepted. All probes were grounded to avoid electrical attraction; the manifold was sized to permit maximum gravitational settling during operation of $1/2$ a diameter, and the length of run to the filter holder was kept to the absolute minimum.

The reduction in the number of sampling holes between probes 1 and 2 was made in order to increase the hole size while retaining the other desired conditions when it was feared the small sampling aperture might be acting like a filter. This, however, did not prove to be the case.

The third probe was made by placing 3" long teeth over the sampling holes of probe 2. This was done in order that sampling could be achieved without the turbulent effects possibly created by the surface of the manifold tube itself in the path of the stack flow.

The sample was drawn out of the stack, passed through the filter paper, through a flowmeter (with a vacuum gage for use in correcting the flow to stack conditions) to the vacuum pump, and then discharged to the atmosphere. One of two types of filter paper was used in each run: either H and V 70 (9 mm paper) fixed in a holder mounted on the end of the manifold tube, or Type HA Millipore paper (0.45μ pore size) in a millipore holder. The reported retaining efficiencies of both papers are above 97% for the face velocities employed during the tests.

Probes were placed in the stack in a north-south position or in an east-west position at an upper sampling level about 6 feet below the top of the stack, or in a north-south position at a lower sampling level about 18 feet below the top of the stack. For all runs except 1, 2, and 7, the probes were cleaned before use by washing and leaching in 5% nitric acid for an extended period of time.

Choice of Spiking Equipment

A Schutte and Koerting No. 231 Pyrex Syphon Ejector was used to introduce the spike into the stack. The arrangement is shown in the Second slide. 25 to 40 lb air was employed as the motive force and spike material was added at the suction inlet of the syphon ejector. As shown in the slide, the spike injection train was mounted on an inlet side duct. It was so positioned that the injected spike and motive air would be directed into the center of the opening in the stack wall for the duct from a release point just a few inches upstream.

Testing Details and Sample Preparation

To start a run, the total stack flow was determined and the sampling train was activated.

The starting sample flow rate and vacuum were noted. The spike was added manually over a

7 to 22-minute time period. The amount of spike added varied from run to run ~~from 14 to 58 micrograms of uranium per ft.~~ ^{such that} ~~average particulate concentrations produced ranged from 14 to 58 micrograms of uranium per ft.~~ ^{such that} ~~upon.~~ ^{such that} At the completion of a run, about 150 grams of uranium-free quartzite sand

were injected for equipment cleanout purposes and the final sample flow rate and the vacuum were noted.

The samples collected fell into three categories:

1. Collections in the filter paper.
2. Smear samples: the deposit on the interior surface of filter paper holder was manually rubbed off by using H and V filter papers.
3. Retainage inside the probe.

The filter paper, once removed from the holder, was leached in boiling 30 wt % nitric acid until the paper was thoroughly digested. Filtering followed to remove the undissolved shreds of paper. These shreds were then repeatedly washed with nitric acid and water to ensure complete uranium removal. The washings were returned to the mother liquor, and the combined solution was sent to the laboratory for uranium analysis. A similar treatment was given to the

were made by measurement of the radiant energy (fluorescence) from pellets of fused NaF pellets and uranium. The emitted radiant energy is proportional to the uranium content. The analysis is reliable to very low sample concentrations.

Computations for total stack emission were made by multiplying the sample catch by the ratio of sample flow to stack discharge rate. The sample flows before and after the test were individually corrected to atmospheric pressure and then averaged before computing the ratio for each run.

As the initial step in the procurement of the sample of particulate matter remaining in the probe interior, the outside had to be cleaned until it was thoroughly free of uranium. This was accomplished by two or three brisk manual applications of dilute nitric acid followed by tap water and distilled water washings. When the exterior cleaning was finished, the probe was submerged with occasional agitation for a minimum of 12 hours in a narrow-diameter bottle containing about 3-1/2 gallons of 5% nitric acid. Upon removal from the solution, the tube was washed with distilled water, and the washings were added to the 3-1/2 gallons. The solution was then boiled down to about 1/2 liter to bring up the concentration for laboratory analysis.

Results

The sample collections on the filter paper for each of the individual test runs are shown in the ^{3rd} slide versus the sample theoretically expected if the sampling were unequivocally representative. In the interests of simplicity, the test conditions for each run are not shown. Nevertheless the plot speaks for itself: the total sample expected did not reach the filter paper mounted on the exterior of the stack customarily used for determination of stack losses.

During the progress of the experiments, it was found necessary to adjust the sample flow rate in order to maintain design conditions. Changes in the flow rates, the spiking rate, the motive air pressure, and the mean concentration of spike material in the exhaust (~~1.4 to 58 micrograms~~ ^{per cu. ft.}) produced no discernable trends. In all cases the theoretical sample collection for a run was computed based on the amount of spike and the average flow rates for the run with all flows corrected to stack conditions.

The test data have been summarized for the other test conditions in Slide 4 in terms of the percentage of the theoretical collection actually found in the filter paper. The results are shown when different probe locations or different filter papers are used, and when teeth are added to the probe. The collection percentage realized actually represents the operation efficiency of the probe.

The test efficiencies ranged between 12 and 38% with the overall at 25%. For the few runs in which probes with holes rather than teeth were used, the amount collected was 17% - considerably less than the overall average. The average efficiency for all runs using millipore paper was 22%; for runs using H and V 70 paper, 29%. The amounts collected for all the runs at the upper level averaged essentially the same as those for the runs at the lower level.

For the most part, smear samples showed low uranium content. As a result, they are not considered as being of much more than academic interest. However they were handled in the rest of the tests that followed.

At this point it was undertaken to determine what happened to the rest of the sample expected. Material balances were made for several of the runs by totalling the amounts collected in the filter paper, on the smears, and inside the toothed probes and comparing the result with the theoretical sample collection. The results are shown in Slide 5. Obviously, much of the expected sample can be accounted for by the retainage inside the probe. Balance closures for the various runs ranged from 4 to 167%, but only a few balances closed poorly. The overall closure is with 24%.

It was felt that support tests for the previous work were called for, in order to:

1. Assure that the full amount of the injected spike was passing the sampling levels and thus available to the inserted test probes.
2. Determine if there are any major changes in particle sizing as the material passed up the stack. In such an eventuality, efficiency results could be biased.
3. Demonstrate whether the experimental facts would be borne up by field experience.

"Inside - stack" probes were used to examine the first point. A typical experimental setup and the data collected as shown on Slide 6. For each run, two of these probes were mounted at about the same level at right angles to each other so that five sampling ports were in operation, designed to draw off 5 samples from the centers of 5 equal areas. The upper sampling level in the test stack was used for all these runs.

Two vacuum pumps were used with each probe in order to draw samples through the large 3/16"

sample nozzles under conditions as isokinetic as possible. Millipore paper, type HA, was mounted in the filter holders with each nozzle. Testing, sampling preparation, and computations were the same as for the traverse type probes.

The actual collection data for the tests demonstrate the uneven particulate distribution over the cross-section of the rising exhaust stream. Total collections for the inside-stack probes did not differ by more than 6.5% from theoretical. It was concluded that for the test runs, the full amount of the injected spike did indeed pass the sampling probes.

A particle size distribution analysis for both the injected spike and filter paper samples taken during one of the spike tests was made using electronmicroscopic methods. The results are shown in Slide No. 7. The material in the sample is somewhat smaller, suggesting a breakup of particles in the stack stream and/or a loss of the larger particles inside the probe. It was felt that the size differences found were easily explained by mechanisms which would not bias the test results in a major manner.

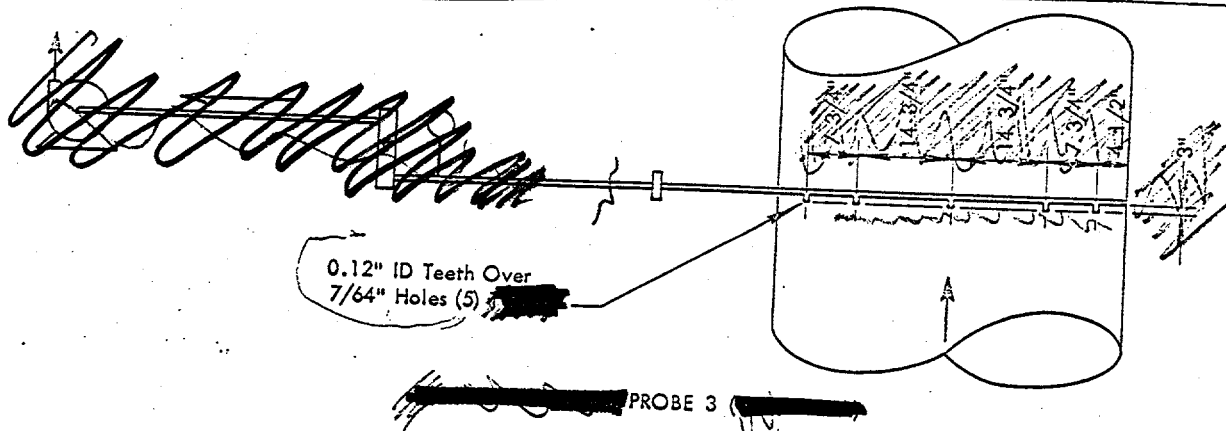
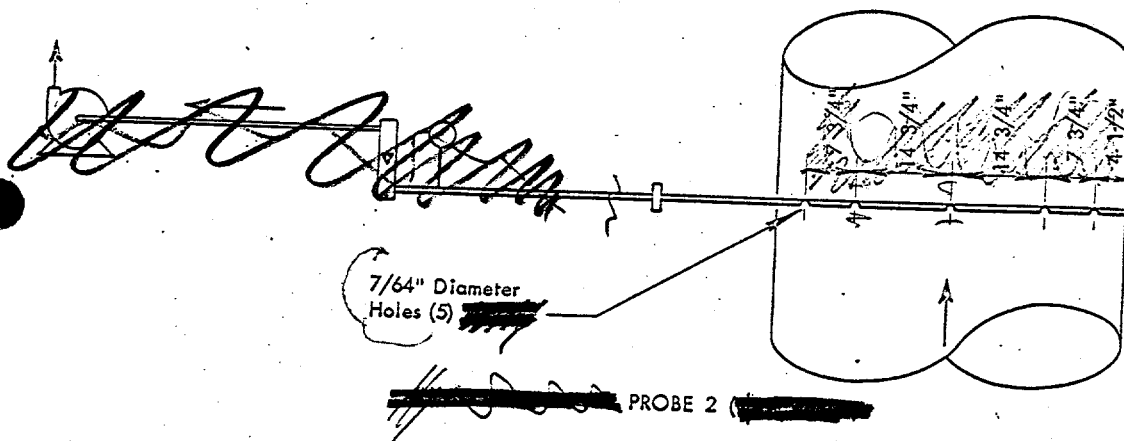
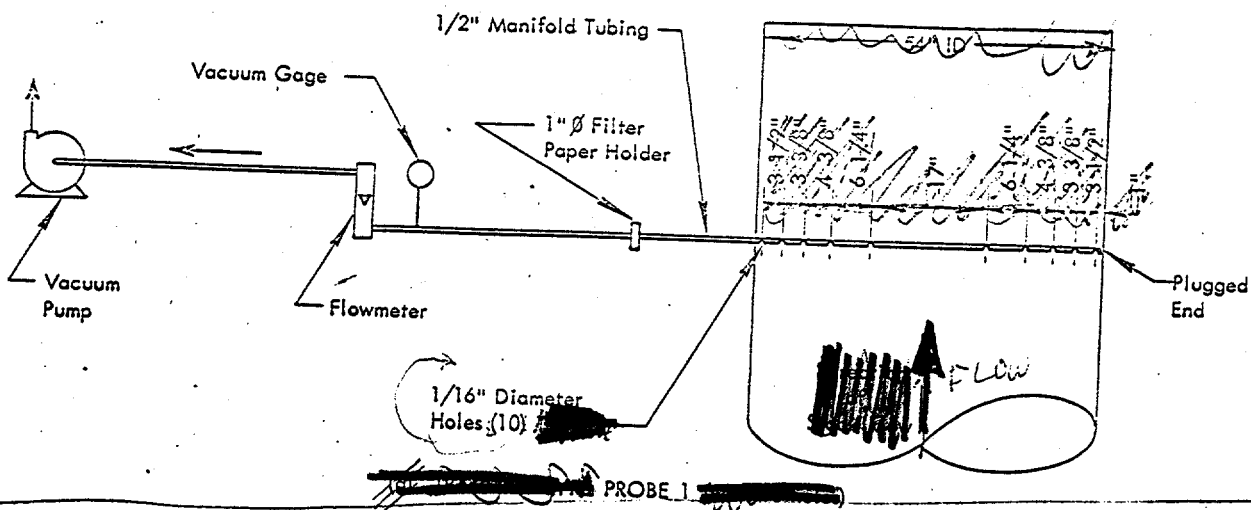
Some routine collection data by the traverse rake-type probe in two regular plant stacks are shown in Slide 8. Although the total uranium particulate flows in the stacks were unknown, the relation between the collection of sample in the filter paper versus the amount retained inside the probe could be determined for comparison with the experimental data. The new tests were run for long periods of time ranging from 30 to 63 days. Filter papers and smear samples were taken daily and the probe was cleaned at the end of the test. Under such circumstances, the material collected on the daily filter paper samples varied from 16 to 51% but averaged 31% of the total amount obtained from filter paper, smears, and cleaning of the probe interior as compared to about 28% in the experimental runs.

CONCLUSIONS

In summation, the traverse rake-type probe represented what was felt to be a practical, superior device, easily adaptable to an existing plant installation for the measurement of stack losses. The probe took representative samples during the tests, yet only a portion of the amount entering the probe reached the sample outside the stack.

Unfortunately, therefore, use of this probe is subject to pitfalls in spite of the intent of the design. Field tests should precede its application in any situation.

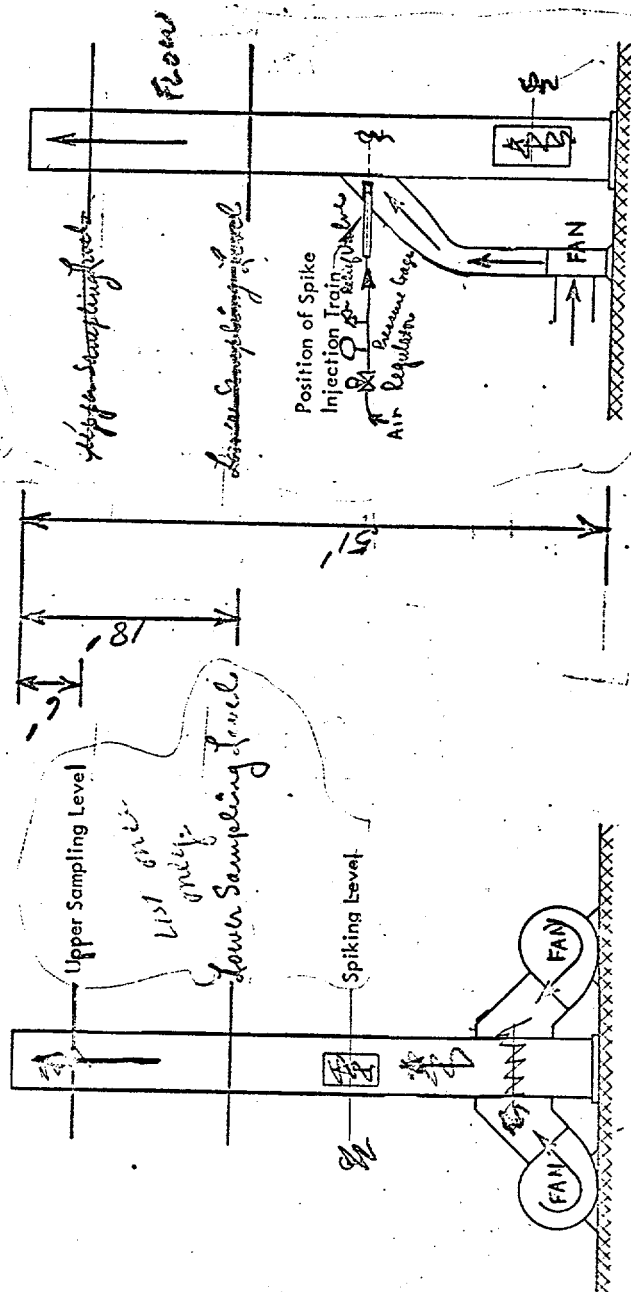
SLIDES 1 - 8



TRAVERSE-TYPE STACK PROBES USED IN TESTS.

SLIDE 1

#2



THE STACK USED FOR THE SPIKE TESTS.

SLIDE 2

#3

✓

COLLECTION OF PARTICULATE MATTER
DURING TESTS

Block Theoretical Sample
Collection

Actual Sample Collected

* Scale 0-100

RELATIVE AMOUNTS OF URANIUM EMITTED

Relative Amounts
of Uranium Emitted

TEST RUNS

#4

Summation of Data: Collection of Particulate
Matter on ~~the~~ Filter Paper Samples

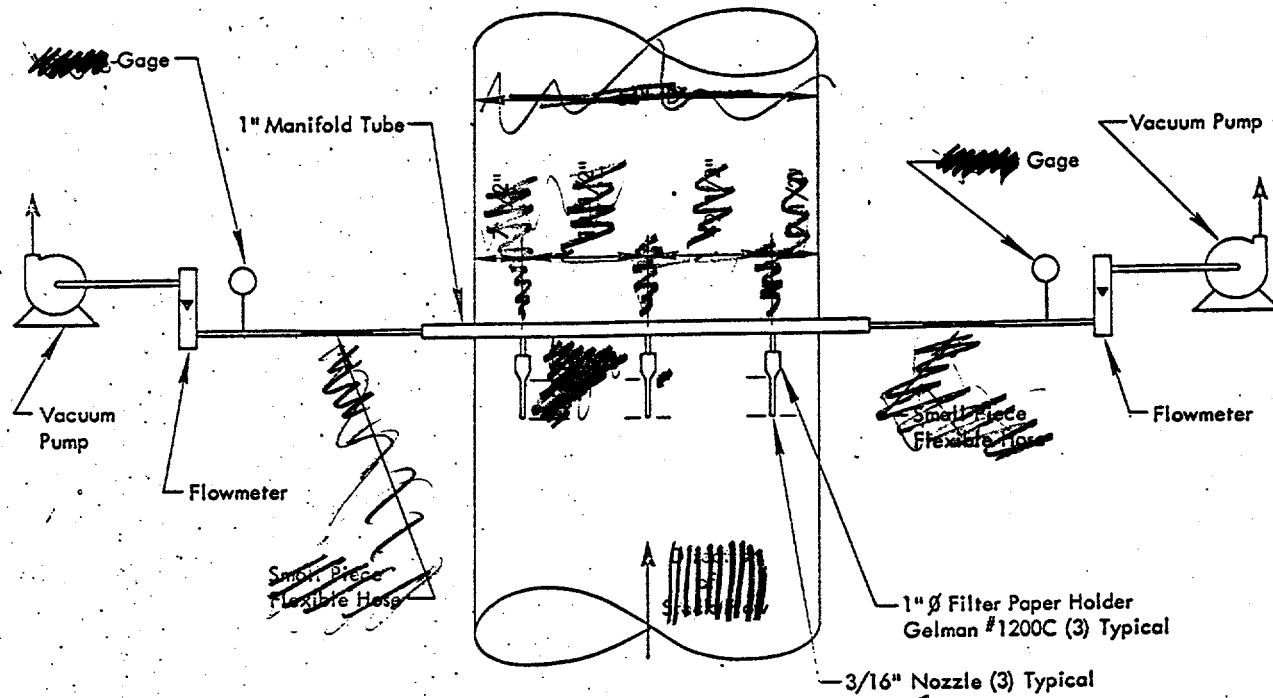
<u>Test</u> <u>Conditions</u>	<u>Filter</u> <u>Paper</u> <u>used</u>	<u>Probe</u> <u>Level</u>	<u>Percent of Theoretical</u> <u>Collection Found in</u> <u>Filter Paper Sample</u>
Changing the Paper:	Millipore	Upper & Lower	27
	H4 V 70	" "	29
Changing the Sampling	Both	Upper	25
Level	both	Lower	24
Using Probs without Teeth	both	Upper	17
Using Travers Rake Type	both	Upper & Lower	28
Grand Totals All Tests	Both	Upper & Lower	25

#5

Material Balances Using Reverse-Rake-Type Probe

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	<u>Probe</u> <u>Level</u>	<u>Theoretical</u> <u>Sample</u> <u>Collection</u> <u>(mg U)</u>	<u>Total</u> <u>Actual</u> <u>Collection</u> <u>(mg U)</u>	<u>Material Balance</u> <u>Closure for</u> <u>Collection</u> <u>(%)</u>
1)	Upper	690	1082	+57
2)	Lower	670	622	-7
3)	Upper	317	286	-10
4)	Lower	332	348	+5
5)	Upper	306	318	+4
6)	Lower	298	329	+10
7)	Upper	108	288	+167
8)	Lower	110	169	+54
9)	Upper	238	210	-32
10)	Lower	257	23	+11
11)	Upper	297	438	+45
12)	Lower	293	348	+26
13)	Upper	265	319	+96
14)	Lower	262	301	+15
15)	Upper	130	152	+41
16)	Lower		124	+15
	<u>Totals</u>	<u>1600</u>	<u>5755</u>	<u>+24</u>



TYPICAL INSIDE-STACK PROBE

✱

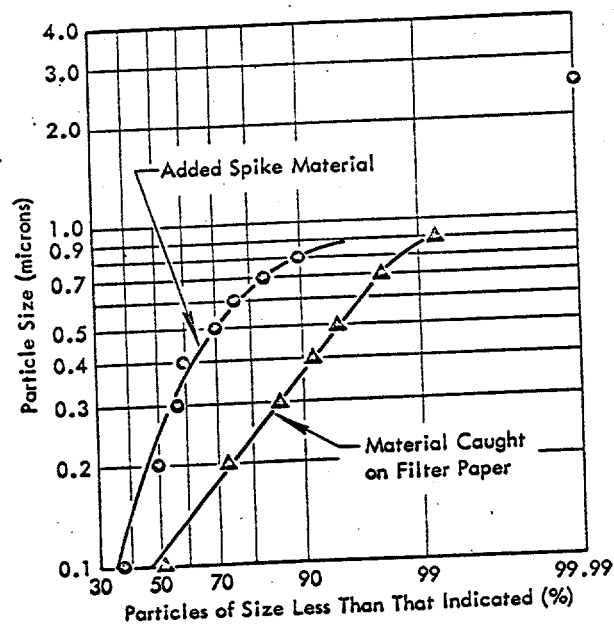
Collection of Particulate Matter
(using inside-stack probes)

Total Theoretical Sample Collection ($\mu\text{g U}$)	Actual Collection Thru Nozzle ($\mu\text{g U}$)					TOTAL	Material Balance for Collection (%)
	NW	Center	SE	SW	NE		
1280	465	229	114	92	299	1199	-6.3
1170	399	285	90	84	324	1182	+1.0
465	196	110	36	43	110	495	+6.5

- (1) By theoretical sample collection is meant the amount to be expected (based on theoretical sample flow vs. stack flow) if the sampling is unequivocally representative. Equation 1 is used for the computations.
- (2) $\frac{\text{Actual Collection} - \text{Theoretical Collection}}{\text{Theoretical Collection}} \times 100$

#6

#7



PARTICLE SIZE DISTRIBUTION FOR
THE SPIKE INJECTED vs THE STACK SAMPLE
COLLECTED.

Slide

